June 15, 1948. R. P. HEUER 2,443,424

BRICK HAVING LOW MODULUS RUPTURE

Filed May 12, 1944 2 Sheets-Sheet 1

Fig. 1.

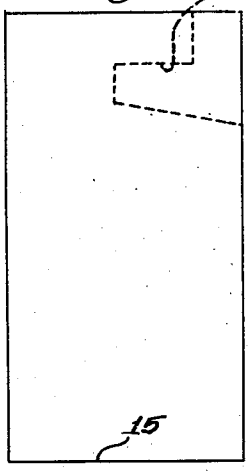


Fig. 2.

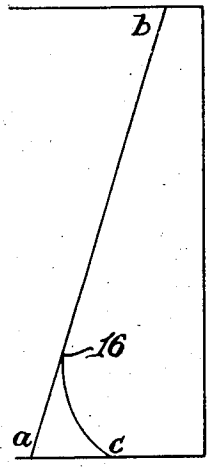


Fig. 3.

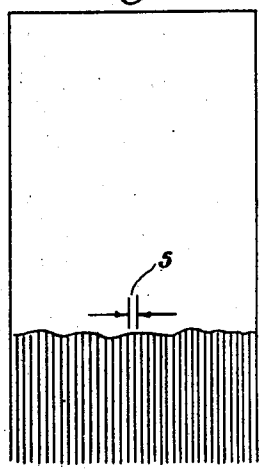
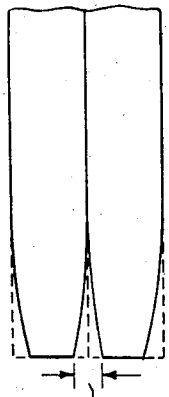


Fig. 4.



$\Delta S = S \div (T_1 - T_2)$

Fig. 5.

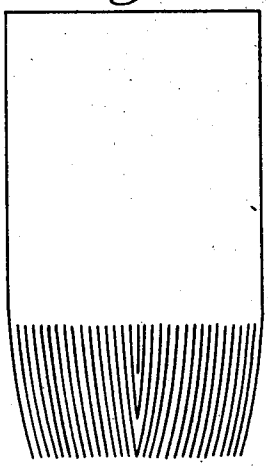
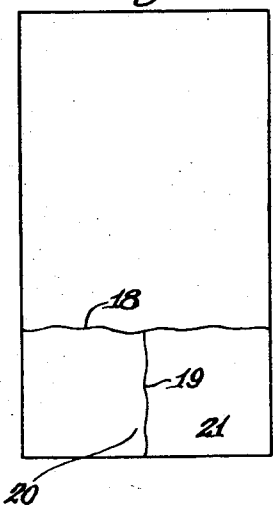


Fig. 6.



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BRICK HAVING LOW MODULUS RUPTURE

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Fig. 8.

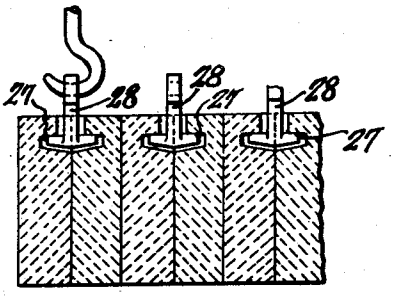
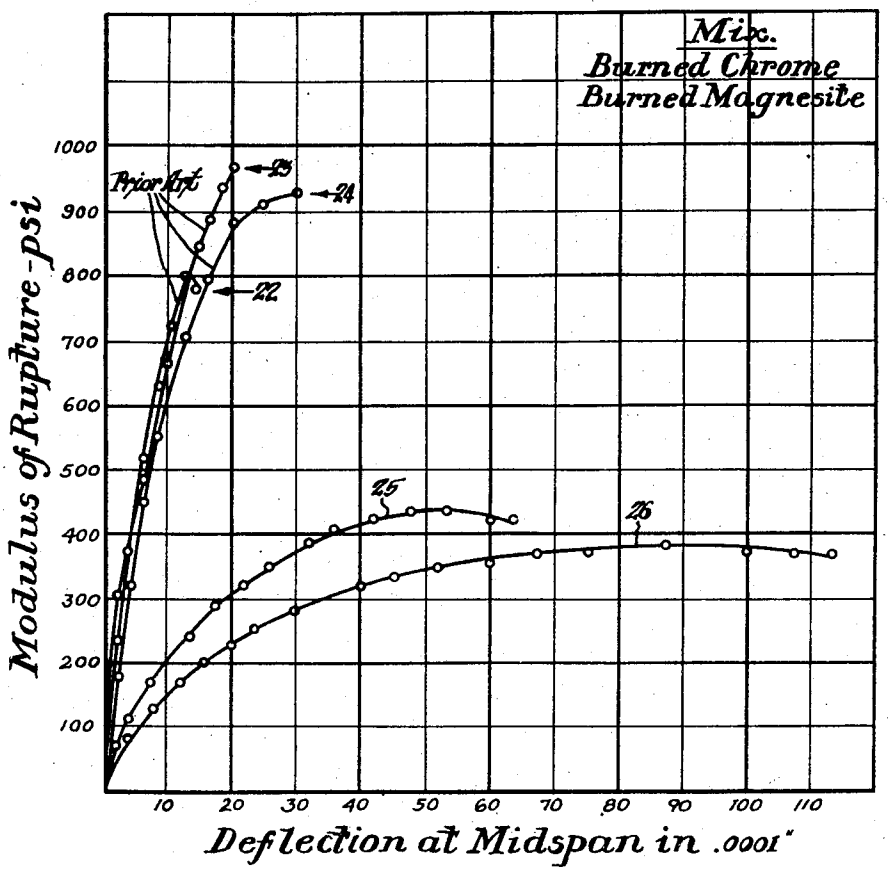


Fig. 7.



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UNITED STATES PATENT OFFICE

2,443,424

BRICK HAVING LOW MODULUS RUPTURE

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Application May 12, 1944, Serial No. 535,360

16 Claims. (Cl. 110—99)

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My invention relates to the manufacture of basic refractories comprising chrome ore and dead burned magnesite or periclase.

One purpose of my invention is to manufacture basic refractory brick having high resistance to spalling which are characterized by a low modulus of rupture or low crushing strength after heating to high temperature.

A further purpose is to produce basic refractory brick which have a low modulus of rupture after being heated to high temperature by using a mixture of chrome ore and magnesite having a novel distribution of particle size and weight ratio of chrome ore to magnesite which accomplishes this objective.

A further purpose is to provide basic refractory brick having a higher resistance to crushing strains before firing than after firing and an abnormally low modulus of rupture after burning.

A further purpose is to increase the resistance to spalling and reduce the modulus of rupture in a burned basic refractory brick by the use of dead burned magnesite and chrome ore, the magnesite in excess of the chrome ore, made up of relatively large particles and relatively small particles and omitting intermediate particles.

A further purpose is to use a brick which has a low modulus of rupture or a low crushing strength and to protect it from crushing by suspending it within a roof in which it is to be used.

A further purpose is to avoid spalling by weakening the brick and then make up for this weakening by suspending the brick from the roof instead of supporting them in the usual sprung arch roof.

A further purpose is to provide a brick which is of low porosity and yet strong enough to be handled and shipped, which has low volume shrinkage when heated to a high temperature range such as is found in open hearth steel furnaces and which is resistant to iron oxide attack.

A further purpose is to provide a brick made of larger size chrome and magnesite particles and small size chrome and magnesite particles, lacking in the intermediate particles, all in oxide form, preferably using also finely ground aluminous material such as bauxite.

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A further purpose is to provide a chrome and magnesite brick having relatively large and relatively small particles of each and lacking the intermediate particle sizes, to add a small amount of temporary bonding material such as sulphuric acid, magnesium chloride, magnesium sulphate or organic binders, etc. to increase the strength of the dried brick before firing, with the result that the brick can be used without kiln burning.

A further purpose is to form a brick having resistance to crushing strain higher in its unfired condition than in its burned condition, to transport the brick while dry and unfired and burn it in place and to separately support the brick in position within the roof of the furnace.

In the manufacture of basic refractory brick intended primarily for use in the roof of an open hearth steel furnace, a further purpose is to take advantage of suspended support for the roof brick to permit the use of brick of low modulus of rupture designed and effective to protect against spalling and which could not be used in sprung arches because of the compressive stresses there.

In the manufacture of a basic refractory roof brick for use primarily in an open hearth steel furnace, a further purpose is to reduce spalling by reducing the modulus of rupture or crushing strength, thus making the brick when burned unsuitable to use within a sprung arch and to make these bricks available, notwithstanding the mechanical objection introduced by this feature, by suspending the bricks.

Further purposes will appear in the specification and in the claims.

The illustrations are all diagrammatic except one which has been included showing one form of suspended brick arch which has been taken from Figure 17 of my Heuer Patent No. 2,304,170 of December 8, 1942.

Figure 1 is a diagrammatic view showing a brick intended for suspended arch use in a vertical side elevation, the lower edge of the brick being exposed to the fire.

Figure 2 is a diagrammatic view giving the length of the brick in order that there may be plotted upon it the temperature gradient within a brick when in roof service.

Figure 3 is a diagrammatic side elevation in

part broken at the bottom to illustrate the behavior of the brick.

Figure 4 is a fragmentary enlarged diagrammatic illustration showing two adjacent laminae among those in Figure 3.

Figure 5 is a side elevation in which the effect in Figure 4 has been plotted in the laminae shown in Figure 3.

Figure 6 is a diagrammatic side elevation showing the action of spalling upon the brick.

Figure 7 is a diagrammatic view containing curves plotted comparatively to indicate modulus of rupture along one dimension plotted against deflection at midspan plotted at right angles thereto.

Figure 8 is a fragmentary section of a suspended brick roof made of bricks from materials such as are claimed herein.

In the drawings similar numerals indicate like parts.

For the construction of roofs for open hearth furnaces it is customary to use silica brick. The roof is formed by springing an arch to span the furnace from skewbacks located in the furnace sidewalls. Steel tie rods apply a horizontal compressive force to the skewbacks and roof brick. A vertical component of force is thereby produced in the arch to support it against the force of gravity. The compressive forces acting on the roof brick are substantial and a desirable refractory for this use should have a sufficiently high crushing strength to withstand the forces present.

Efforts have been made to build sprung arches in metallurgical furnaces from refractory brick other than silica. Trials have been made with basic brick comprising chrome ore and/or magnesite in sprung arches with indifferent results.

I have found that spalling is much more pronounced where the modulus of rupture is high and where the strength to resist crushing is high and that the spalling is greatly reduced by reducing the strength to resist crushing. However this introduces difficulties in supporting the arch because the relatively high compressions on the bricks necessary to support the customary sprung arch tend to destroy the brick and make such a sprung arch brick impractical. However, I have found that the bricks can still be used in furnace roofs if the type of the roof be changed radically and in place of the sprung arch the roof be formed of suspended bricks in accordance with the teachings of my United States Patent No. 2,304,170.

I have successfully used suspended basic brick roofs for sprung silica brick roofs in large copper reverberatory smelting furnaces. In this case the copper furnace was a continuous furnace and the temperature changes in the roof were held to a minimum. However, when similar suspended roof bricks using conventional basic bricks made of chrome ore and magnesite were used in basic open hearth steel furnaces, the results were not comparable with those obtained in the copper smelting furnaces. One reason for this was that the open hearth furnace is an intermittent furnace and the temperature of the roof changes substantially during each successive heat. The changing temperature in the open hearth furnace causes the brick to fracture and spall off along planes which are parallel to the exposed face of the brick and about 1" from the heated end. This spalling causes premature failure of the roof.

The reason for the poor operation when using existing basic brick in the open hearth steel furnace will now be explained in connection with Figures 1 to 6.

In Figure 1 the lower face of the brick represented by line 15 is exposed to the heat of the furnace, the vertical faces being protected by adjacent brick. This lower (hot) face of the brick may show a temperature of 3000° F. at the time a finished heat of steel is tapped from the furnace.

A thermal gradient prevails along the longitudinal axis of the brick as shown by the line *ab* in Figure 2. After the furnace is tapped the furnace doors are opened, the fuel is shut off and a large quantity of cold charge is placed in the furnace. As a result the hot face of the brick is cooled rapidly and its temperature may fall 1000° F. or more. The line *cb* in Figure 2 represents the new condition schematically. Since the cooling is relatively rapid, most of the temperature change is confined to the end of the brick. At some interior point such as 16 there is relatively little loss in temperature.

After charging is finished the fuel is again supplied to the furnace and the hot face of the brick rises in temperature until the gradient shown by the line *ab* is again established. This operating cycle is repeated again and again. The brick are subjected to repeated strains and finally fractures develop and the hot faces of the brick spall off. The new hot faces are subjected to a similar treatment and gradually the brick are destroyed.

Figure 3 may be used to show the mechanism whereby these spalling cracks develop. In this figure the heated end of the brick shown in Figure 1 is represented as being composed of a number of elements of thickness S across the width of the brick. The strips here represented have extent, let us say, from one side of the brick to the other a total of 2½".

If each element were free to act independently when the temperature falls from T_1 to T_2 the dimension S would decrease in amount equal to $Sa(T_1-T_2)$—(where "*a*" is the coefficient of expansion). Figure 4 shows two of these assumed elements on an enlarged scale and illustrates what the effect of this change in the dimension would be if the elements acted independently. In the actual brick, however, each element S is firmly attached to its neighboring element throughout the lengths and widths of the elements.

In order to maintain this continuous structure the individual elements must undergo strains in amount sufficient to compensate for the change $Sa(T_1-T_2)$. This is accomplished in two ways. Tensile stresses are set up across the hot face of the brick which increase the thickness of the individual elements. In addition the adherence of each element to its neighbor tends to conform the adjoining elements to each other. This conformation plus the tensile strain attempts to compensate for $Sa(T_1-T_2)$. The assembly of the strained elements is illustrated in Figure 5.

The tensile stress acting across the hot face may rise to a value which the refractory material cannot stand, whereupon a crack will result at about 90° to the hot face, as shown at 19, Figure 6. The deformation of the elements at the edge of the brick may exceed the strain which the refractory is capable of withstanding, whereupon a crack such as 18 in Figure 6 will start and then gradually work across the brick. Cracks similar to 18 and 19 are observed in actual practice. As

a result of the cracks, portions such as 20 and 21 separate from the brick and fall off as spalls. Of the two types of cracks indicated the cracks 18 are more destructive.

In the foregoing study only the forces caused by cooling have been considered. Upon rapid heating, compressive forces are set up across the face of the brick. Deformation of the individual brick elements also occurs but in an opposite direction to the deformation caused by cooling. If the compressive forces are large enough they may cause shearing stresses and consequent cracking of the refractory. In basic roofs these shear cracks are seldom observed. However, the effect of deformation of the brick elements, upon heating, supplements the destructive deformation caused by cooling and may therefore cause failure more rapidly.

In order to increase the resistance of basic brick to spalling it is necessary to increase the resistance of the brick to repeated deformation.

I have been able greatly to increase the deformation obtainable in basic bricks as a result of studies I have made on the behavior of various kinds of brick when subjected to modulus of rupture tests.

The apparatus for making this test is the standard equipment recommended by the American Society for Testing Materials and described in that society's publication "Manual of A. S. T. M. Standards on Refractory Materials" June 1943 on pages 65–66 under the A. S. T. M. designation C133–39. The test is therefore their standard test. A standard size brick, 9 x 4½ x 2½" is used. The brick is first reheated to 1500° C. for 24 hours, then cooled to room temperature and subjected to the test. The sample brick is tested as a beam resting on two transverse bearing edges 7" apart. A load is applied to the 9" x 4½" face along a line parallel to the two supports and equidistant between them. The deflection of the beam is measured in units of 0.0001 inch at the place where the load is applied. The load is gradually increased until failure occurs and the deflection is noted for various loads applied. The modulus of rupture is calculated from the load required at failure by the formula.

$$R=\frac{3Wl}{2bd^2}$$

where:

R=modulus of rupture in pounds per square inch,
W=total load in pounds at which the specimen failed,
l=distance between the supports in inches,
b=width of the specimen in inches, and
d=depth of the specimen in inches.

For intermediate loads a similar fibre stress is calculated and the corresponding values plotted against the deflection.

In Figure 7 curve 22 shows test data plotted for a conventional burned chrome brick. The shape of this curve is typical of strong, hard burned basic brick. The modulus of rupture is high (797 pounds per square inch) and the deflection just before failure is very small (0.014").

Curve 23 represents a typical burned magnesite brick. Its deformation at failure is greater than the burned chrome brick and its spalling resistance is better. In recent years improved basic brick having still better spalling resistance than straight magnesite or chrome brick have been made from mixtures of about 75% chrome ore and 25% magnesite. Curve 24 represents test

data on commercial burned chrome-magnesite brick of this type. The deformation of this brick is better than the two preceding types although it still leaves much to be desired as far as deformation is concerned.

I have found that it is possible to produce basic brick having better deformation characteristics by the use of a novel method of distributing the particle sizes and the weight ratio of chrome ore and magnesite in the mix. Two typical refractory bodies (Examples 1 and 2) were made in accordance with the present method and tested for modulus of rupture and deflection. The results are shown in curves 25 and 26, Figure 7.

At the point of ultimate failure these new bodies show a deflection more than 2 to 8 times greater than with the conventional refractories referred to above. Comparative data are assembled in Table 1.

Table 1

	ϵ	R
Burned Chrome brick (22)	0.0014	797
Burned Magnesite brick (23)	0.0020	969
Burned chrome-magnesite brick (24)	0.0030	930
Example #1 (25)	0.0064	438
Example #2 (26)	0.0114	365

This greater deflection causes a vastly greater resistance to spalling with subsequent longer life of the refractory under operating conditions. In Example 26 a maximum of deflection has been obtained by purposely making the refractory weak and of low modulus of rupture. The lower the strength of the brick the better it conforms to the requirements which are necessary for best spalling resistance.

In applying the new type of weak refractory commercially the limitations of its strength must be specifically provided for and wherever possible it is recommended to be used in suspended roof construction and in similar mechanically supported parts of furnaces. Such a suspended construction does not require the high physical strength which has heretofore been considered a necessary property of a basic refractory. Thus by choosing a suitable mechanical construction I am able to successfully utilize a refractory of low modulus of rupture and in so doing I obtain a vast improvement in spalling resistance which has not been obtained heretofore with the conventional types of basic brick.

The manufacture of a basic brick of minimum modulus of rupture after reheating to 1500° C. and subsequent cooling is not the simple problem that it may seem to be. While many of the recent "improvements" in basic brick manufacture are said to produce "hard burned" brick of "unusually high strength" by the use of special high-temperature kilns, high forming pressure and the use of selected particle sizes in the mix, it does not necessarily follow that low modulus of rupture is easily obtained by merely doing away with all or most of these recent developments.

In obtaining the low modulus of rupture other desirable properties of the brick must not be sacrificed. The refractory must be dense, i. e., of low porosity and be strong enough to be handled and shipped, must not show excessive volume shrinkage when heated to high temperature and, in the case of brick to be used in open hearth steel furnaces, must be resistant to iron oxide attack.

The raw materials for making this brick of low modulus of rupture comprise principally

chrome ore and dead burned magnesite or periclase.

A suitable chrome ore is the refractory grade ore obtained from the Masinloc deposit on the island of Luzon, Philippine Islands. Chrome ore from the Moa Bay district of Cuba is also satisfactory. Typical analyses follow:

Table 2

	Masinloc	Moa Bay
	Per cent	*Per cent*
Ignition Loss	0.45	0.05
SiO_2	3.64	1.50
FeO	13.53	13.62
Al_2O_3	30.64	28.29
CaO	0.19	0.14
MgO by diff.	17.94	17.82
Cr_2O_3	33.62	38.58

Other refractory ores higher in chromic oxide may also be used. The ore may be used in its raw or natural state or after calcining at high temperature if desired.

The desired chrome ore is first crushed in a jaw crusher and then passed through a conventional muller-type perforated-bottom dry pan to grind the ore for screening and selection of certain desired particle sizes to be used in the brick mix. Since a preponderant amount of the chrome ore is used in the form of relatively coarse particles, the choice of the ore and the method of grinding should be made such as to produce a maximum of coarser particles and a minimum of finer particles in the first grinding operation, otherwise a large amount of the chrome ore will be too small in size for ultimate use and will therefore be rejected.

The ground product which passes through the perforated bottom of the dry pan is screened over suitable vibrating screens to obtain a product which passes substantially 100% through a W. S. Tyler standard screen of 6 meshes per linear inch. Whatsoever oversize there may be is returned for further grinding in the dry pan and further screening. In order to minimize the production of too many small sized particles, it may be desirable to pass the ore as it comes from the crusher over the first screen before it goes to the dry pan.

The ground chrome ore which passes the first screen is then passed over a second vibrating screen which is designed to pass all particles which are small enough to go through a W. S. Tyler standard screen of 28 mesh per linear inch. The product which fails to pass this screen is set aside for subsequent use as coarse chrome particles. Particles which pass 6 mesh and rest on 28 mesh standard screens are preferred.

The size of the openings of the first screen may be increased to produce particles which will only pass the equivalent Tyler standard screens of 5 mesh per linear inch. The size of the screen openings may alternatively be decreased so that the screened particles will just pass a W. S. Tyler standard screen of 8 or 10 mesh per linear inch. The size of the openings in the second screen in similar manner may be increased so that the product will rest substantially all on W. S. Tyler screens of 20 mesh or the size of the openings may be decreased so that the product will rest substantially all on a 35 mesh Tyler screen. The difference in the size of the openings in the first and second screen should be kept reasonably small so that the range in size of the coarse chrome particles is not excessive. Thus screening combinations of 6 and 28 mesh, 5 and 20 mesh or 10 and 30 mesh are practical selections designed to give desirable production and good costs. I prefer the 6 and 28 mesh combination for most uses but the other sizes may be used if desired.

In preparing the chosen sizes commercially, using for example, the 6 and 28 mesh combination, the product will usually contain some particles which, on laboratory test, will pass a 28 mesh standard screen. Such product can be used but the amount of particles passing the 28 mesh standard screen should be kept to a minimum. Typical screen analysis follows:

Table 3

	Per cent
On 6 mesh	0.4
On 8 mesh	26.7
On 10 mesh	26.3
On 20 mesh	34.5
On 28 mesh	3.2
On 35 mesh	3.9
Thru 35 mesh	5.0

The finer sized chrome particles which pass the second screen are now passed over a third and finer vibrating screen. All particles passing through this screen are set aside for subsequent use as fine chrome particles. The particles which do not pass through the third screen are reground in a ball mill or similar fine grinding device and returned to the third screen.

The size of the openings of the third screen is chosen so that the product will pass substantially through W. S. Tyler standard screen of 50 or 65 mesh per linear inch. Typical screen analysis follows:

Table 4

On 48 mesh	nil
On 65 mesh	10.0
On 100 mesh	13.0
Thru 100 mesh	77.0

I have found that this product can be readily produced in commercial quantities at low cost and a product of this degree of fineness makes a satisfactory brick. However, for certain special uses and where the increased cost is not objectionable the fine chrome particles may be chosen to pass substantially all through a W. S. Tyler standard screen of 100 mesh or 150 mesh per linear inch or even 200 mesh or 250 mesh per linear inch.

The dead-burned magnesite which is used may be prepared by calcining magnesium hydroxide prepared from sea water as disclosed in my pending U. S. patent application, Serial No. 411,695. Periclase or other types of calcined or fused magnesia are considered as materials equivalent to dead-burned magnesite for the purposes of this disclosure. Typical analyses are the following:

Table 5

	Sea Water Magnesite	Periclase
	Per cent	*Per cent*
Ignition Loss	0.10	0.09
SiO_2	1.21	5.71
Fe_2O_3	3.01	0.36
Al_2O_3	0.85	0.70
CaO	3.82	1.34
MgO by diff.	91.01	91.80

Preferably the calcining should be done at temperatures of 1500° C. or 1600° C. or more and the bulk specific gravity of the calcine should exceed 3.30. Dead-burned magnesite from other sources

may also be used, as for example, the product obtained by calcining natural magnesite (magnesium carbonate), brucite or other suitable minerals. Typical analyses of such dead-burned magnesites are:

Table 6

	Manchurian Dead-burned Magnesite	Austrian Dead-burned Magnesite
	Per cent	*Per cent*
Ignition Loss	0.12	0.06
SiO_2	3.24	0.53
Fe_2O_3	1.05	8.31
Al_2O_3	1.11	0.29
CaO	1.96	2.49
MgO by diff.	92.52	88.32

The magnesite is ground and screened to proper particle size using the general procedure as outlined above. The size of the first, second and third screens should be chosen in conformity with the principles described above. Coarse magnesite particles preferably passing through 6 mesh and resting on 28 mesh Tyler standard screens are produced. Other sizes such as passing through 8 mesh and resting on 28 mesh, or passing 10 mesh and resting on 30 mesh, or other desired combinations for specific purposes can be chosen. Fine magnesite particles passing through Tyler standard screens of 50 or 65 mesh per linear inch are acceptable although for specific purposes particles passing screens of 100, 150, 200 or 250 mesh per linear inch may be chosen. A satisfactory screen analysis of typical coarse and fine magnesite particles is the following:

Table 7

Coarse magnesite particles, percent	
On 6 mesh	trace
On 8 mesh	7.3
On 10 mesh	26.6
On 20 mesh	53.4
On 28 mesh	9.8
On 35 mesh	2.0
Thru 35 mesh	0.9

Table 8

Fine particles, percent	
On 48 mesh	nil
On 65 mesh	10.0
On 100 mesh	16.0
Thru 100 mesh	74.0

In addition to the chrome ore and magnesite it is quite desirable that a substantial quantity of finely ground bauxite be incorporated into the brick mix. A low silica bauxite such as that produced in Surinam is satisfactory. Typical chemical analysis is the following:

Table 9

	Percent
Loss on ignition	29.62
SiO_2	4.54
Fe_2O_3	2.29
Al_2O_3	60.21
TiO_2	2.76
CaO	0.09
MgO	0.42

The bauxite is ground to pass substantially all through a Tyler standard screen of 65 mesh per linear inch, or 100 mesh or finer, as desired. Raw bauxite is a satisfactory material although other high aluminous materials such as calcined alumina hydrate (prepared in the Bayer process for treating bauxite) or fused alumina may also be used.

I have secured excellent results with aluminous material comprising 50% or more of alumina on the calcined basis with the remainder chiefly silica and iron oxide, having a P. C. E. in excess of cone 33.

As an alternative small quantities of raw kaolin may also be required. This material may analyze as follows:

Table 10

	Percent
Loss on ignition	13.54
SiO_2	42.64
Fe_2O_3	3.81
Al_2O_3	37.31
TiO_2	1.48
CaO	0.09
MgO	0.71

It should be ground to pass substantially all through a Tyler standard screen 200 mesh per linear inch.

For making the brick, the above ingredients are mixed in the following proportions by weight:

Table 11

	Example #1	Example #2
	Per cent	*Per cent*
Coarse chrome particles	30	30
Coarse Magnesite particles	35	35
Fine Chrome particles	10	10
Fine Magnesite particles	20	23
Bauxite particles	5	
Kaolin		2
	100	100

Mixing is done in a muller-type wet pan. Preferably the muller and the pan bottom are rubber covered to minimize the amount of grinding which may take place while the mixing is done.

A temporary bond is added, such as a solution of sulphuric acid, magnesium chloride, magnesium sulphate, organic binders, etc. to give the proper temper for pressing into brick form. The quantity of solution added should contain an amount of sulphuric acid equal to 1.1% by weight of the dry refractory. If desired sulphite liquor of 31° Baumé about 1.25% by weight of the dry refractory may also be added to increase the strength of the green brick before drying. The tempered brick mix should contain about 4.5% water.

The brick are moulded into shape on a conventional dry press or preferably on a hydraulic press. Pressures exceeding 5000 lbs. per sq. in. are desired and up to 10,000 lbs. per sq. inch or 15,000 lbs. per square inch or more are preferred. By using a high forming pressure and properly chosen particle sizes a brick of low porosity is obtained.

After pressing, the brick are dried at 300° F. prefreably after a preliminary treatment in an atmosphere of high humidity as described in my U. S. Patent No. 2,253,620. The dried brick are suitable for use without further treatment. They have a crushing strength of 5,000 lbs. per square inch or more and can be transported for use without difficulty. In fact, the brick are more suitable for use in the unburned condition than if subjected to a conventional kiln-burning at a temperature of 1500° C., for example. After such treatment the unburned strength is lost and the brick are changed over to the desired condition of low modulus of rupture which is also a condi-

tion of low crushing strength. The burned crushing strength is less than 1,500 lbs. per sq. inch or less than 1,000 lbs. per sq. inch and brick of this low strength cannot always be transported without damage. Shipment in the unburned condition avoids this difficulty. When the unburned brick are placed in use, the heated portion of the brick is converted into the condition of low strength whereupon it automatically becomes suitable for use.

For best results the brick mix should contain 65% by weight of total coarse particles. This amount may be varied, however, within the limits of 55% to 70%. The amount of intermediate particles should be kept to the minimum attainable with ordinary commercial grinding and screening.

The total amount of weight of magnesite in the brick should exceed that of the chrome ore in order to give desirably low strength. The amount by weight of the chrome ore should not be less than 35% in order to avoid excessive shrinkage upon firing to high temperatures. The amount of fine chrome particles should lie between 5% and 15%. If the amount of fine chrome is excessive the brick will be attacked by iron oxide with resultant bursting.

If the amount of fine chrome is too small the brick will shrink excessively when fired to high temperature. If bauxite or similar alumina additions are made the amount by weight should lie between 1% and 10%. If calcined aluminous products are added a larger amount may be used than if raw bauxite is added.

When kaolin or similar alumino-silicates are used the amount by weight should lie between 1% and 4%. After firing to 1500° C. the brick will have a total porosity less than 25%, a modulus of rupture, R, less than 500 lbs. per sq. inch and a deformation, *e*, exceeding .0040" when tested as described herein. Upon reheating to 1650° C. for 5 hours the brick will show a volume shrinkage of less than 1% or less than 0.5% as compared to the original volume of the unburned brick. The brick are very resistant to iron oxide attack.

These brick can be formed into the necessary shapes for constructing suspended roofs and other mechanically supported sections of metallurgical furnaces, such as front walls, back walls, monkey walls, end walls and downtakes of open hearth steel furnaces. For such uses their unusually low strength provides increased resistance to spalling. Because of this low strength the brick are recommended for use in cooperation with means for mechanical support or where such means is not provided they should be used in parts of furnaces where higher structural strength is not required.

An opening **27** is formed in the brick to receive a suspension hook **28**.

Having thus described my invention what I claim as new and desire to secure by Letters Patent is:

1. A basic refractory brick in which dead burned magnesite is the major constituent and chrome ore is present to an extent of at least 35%, the refractory of the brick consisting of a mixture of relatively coarse particles between 5 and 35 mesh per linear inch present to the extent of between 55 and 70% and relatively fine particles below 50 mesh per linear inch, substantially free from particles of intermediate size, in which between 20% and 40% of the mixture consists of relatively coarse dead burned magnesite particles and the modulus of rupture of the refractory body after an initial burning for twenty-four hours at 1500° C. does not exceed 500 pounds per square inch when tested as a 9" x 4½" x 2½" brick acting as a beam 2½" thick supported at locations 7" apart and loaded at midspan.

2. A basic refractory brick in which dead burned magnesite is the major constituent and chrome ore is present to an extent of at least 35%, the refractory of the brick consisting of a mixture of relatively coarse particles between 6 and 28 mesh per linear inch present to the extent of between 55% and 70% and relatively fine particles below 50 mesh per linear inch, substantially free from particles of intermediate size, in which between 20% and 40% of the mixture consists of relatively coarse dead burned magnesite particles and between 5% and 15% of the mixture consists of relatively fine chrome ore particles and from 1% to 10% of the mixture consists of high aluminous material, and in which the deflection of the refractory body exceeds 0.005" when tested for modulus of rupture after an initial burning for twenty-four hours at 1500° C., using a 9" x 4½" x 2½" brick, acting as a beam 2½" thick, supported at locations 7" apart and loaded at midspan.

3. Dry unfired basic refractory brick suitable for used in unfired condition, in which dead burned magnesite is the major constituent and chrome ore is present to an extent of at least 35%, the refractory of the brick consisting of a mixture of relatively coarse particles between 5 and 35 mesh per linear inch present to the extent of between 55% and 70% and relatively fine particles below 50 mesh per linear inch, substantially free from particles of intermediate size, and in which between 20% and 40% of the mixture consists of relatively coarse dead burned magnesite particles and the modulus of rupture of the refractory body after an initial burning for twenty-four hours at 1500° C. does not exceed 400 pounds per square inch when tested as a 9" x 4½" x 2½" brick acting as a beam 2½" thick supported at locations 7" apart loaded at midspan, the dry unfired brick having a volume shrinkage of less than 1% after 5 hours at 1650° C.

4. A dry unfired basic refractory brick, suitable for use in unfired condition, having head burned magnesite as the major constituent and chrome ore present to an extent of at least 35%, the refractory of the brick consisting of relatively coarse particles between 6 and 28 mesh per linear inch present to the extent of between 55% and 70% and relatively fine particles below 50 mesh per linear inch, substantially free from particles of intermediate size, in which between 20% and 40% of the mixture consists of relatively coarse dead burned magnesite particles and between 5% and 15% of the mixture consists of relatively fine chrome ore particles and the modulus of rupture of the refractory body after an initial burning for 24 hours at 1500° C. does not exceed 500 pounds per square inch when tested as a 9" x 4½" x 2½" brick acting as a beam 2½" thick, supported at locations 7" apart and loaded at midspan, the dry unfired brick having a volume shrinkage of less than 0.5% after 5 hours at burning 1650° C.

5. A basic refractory brick having dead burned magnesite as the major constituent and chrome ore present to an extent of at least 35%, the refractory of the brick consisting of relatively coarse particles between 6 and 28 mesh per linear inch, present to the extent of between 55% and 70% and relatively fine particles below 50 mesh

per linear inch, substantially free from particles of intermediate size, in which between 20% and 40% of the mixture consists of relatively coarse dead burned magnesite particles and between 5% and 15% of the mixture consists of relatively fine chrome ore particles and in which the deflection of the refractory body exceeds 0.005" when tested for modulus of rupture after an initial burning for 24 hours at 1500° C. using a 9" x 4½" x 2½" brick acting as a beam 2½" thick supported at locations 7" apart and loaded at midspan.

6. A dried unfired basic refractory brick, suitable for use in unfired condition, having dead burned magnesite as the major constituent and chrome ore is present to an extent of at least 35%, the refractory of the brick consisting of relatively coarse particles between 6 and 28 mesh per linear inch present to the extent of substantially 65% and relatively fine particles below 50 mesh per linear inch, deficient in particles of intermediate size, in which substantially 35% of the mixture consists of relatively coarse dead burned magnesite particles, substantially 30% of relatively coarse chrome ore particles, substantially 20% of relatively fine dead burned magnesite particles, substantially 10% of relatively fine chrome ore particles and substantially 4% of bauxite, the refractory being densely compacted together, having a bonding agent, and having a low modulus of rupture after an initial burning for twenty-four hours at 1500° C. and low crushing strength when tested as a 9" x 4½" x 2½" brick acting as a beam 2½" thick supported at locations 7" apart and loaded at midspan, the dry unfired brick having a volume shrinkage of less than one percent after burning 5 hours at 1650° C.

7. An open hearth steel furnace suspended roof, basic refractory brick having dead burned magnesite as a major constituent and chrome ore present to an extent of at least 35%, the relatively coarse particles passing through a 6 and resting upon a 28 mesh per linear inch screen present to the extent of between 55% and 70%, and relatively fine particles below 50 mesh per linear inch present between 5% and 15%, substantially free from particles of intermediate size, from 20 to 40% being relatively coarse particles of dead burned magnesite, including high aluminous material from 1% to 10% and in which the deflection of the refractory body as outlined in claim 3 exceeds 0.005".

8. Dry unfired basic refractory brick suitable for use in unfired condition, in which dead burned magnesite is the major constituent and chrome ore is present to an extent of at least 35%, the refractory of the brick consisting of relatively coarse particles between 5 and 35 mesh per linear inch present to the extent of between 55% and 70% and relatively fine particles below 50 mesh per linear inch, substantially free from particles of intermediate size, including also from 1% to 10% of finely ground aluminous material, in which between 20% and 40% of the mixture consists of relatively coarse dead burned magnesite particles and the modulus of rupture of the refractory body after an initial burning for twenty-four hours at 1500° C. does not exceed 400 pounds per square inch when tested as a 9" x 4½" x 2½" brick acting as a beam 2½" thick supported at locations 7" apart and loaded at midspan, the dry unfired brick having a volume shrinkage of less than 1% after 5 hours at 1650° C.

9. The process of producing a volume stable basic refractory brick having abnormally low modulus of rupture and corresponding high resistance to spalling in intermittent furnace service, which consists in mixing together dead burned magnesite as a major constituent and at least 35% of chrome ore, in the form of from 55% to 70% of relatively coarse particles passing through a 5 mesh and resting upon a 35 mesh per linear inch screen, and relatively fine particles passing through a 50 mesh per linear inch screen, while substantially omitting particles of intermediate size, and having between 20% and 40% of relatively coarse dead burned magnesite in the mixture, and a bonding agent, forming a mixture pressed into a brick at a pressure exceeding 5000 pounds per square inch, and drying the brick to develop the bond as the final operation without firing prior to furnace use.

10. The process of protecting brick against spalling which consists in forming the brick with a major constituent of dead burned magnesite and at least 35% of chrome ore, having between 55 and 70% of relatively coarse particles between 5 and 35 mesh per linear inch and having relatively fine particles through 50 mesh per linear inch of each, lacking the intermediate sizes, with from 20% to 40% of the mixture of relatively coarse dead burned magnesite and a modulus of rupture below 400 p. s. i. as determined after reheating a standard brick at 1500° C. for 24 hours and testing it under standard A. S. T. M. conditions of test, the brick being unfired and having a higher unfired crushing strength than fired crushing strength after five hours burning at 1650° C. and burning the exposed faces of the unfired brick in place in a suspended furnace roof.

11. The process of producing a volume stable basic refractory brick having abnormally low modulus of rupture and corresponding high resistance to spalling in intermittent furnace service, which consists in mixing together dead burned magnesite as a major constituent and at least 35% of chrome ore in the form of from 55% to 70% of relatively coarse particles passing through a 5 mesh and resting upon a 35 mesh per linear inch screen, and relatively fine particles passing through a 50 mesh per linear inch screen while substantially omitting particles of intermediate size, and having between 20% and 40% of relatively coarse dead burned magnesite in the mixture, inserting from 1% to 10% of a high aluminous material and tempering the mixture, and a bonding agent, forming the mixture into a brick at a pressure exceeding 5000 pounds per square inch and drying the brick to develop the bond as the final operation without firing prior to furnace use.

12. The process of producing a volume stable basic refractory brick having abnormally low modulus of rupture and corresponding high resistance to spalling in intermittent furnace service, which consists in mixing together dead burned magnesite as a major constituent and at least 35% of chrome ore in the form of from 55% to 70% of relatively coarse particles passing through a 5 mesh and resting upon a 35 mesh per linear inch screen, and relatively fine particles passing through a 50 mesh per linear inch screen, while substantially omitting particles of intermediate size, and having between 20% and 40% of relatively coarse dead burned magnesite in the mixture, inserting from 1% to 10% of bauxite and tempering the mixture, inserting a bonding agent, forming the mixture into a brick

at a pressure exceeding 5000 pounds per square inch and drying the brick to develop the bond as the final operation without firing prior to furnace use.

13. The process of producing a volume stable basic refractory brick having abnormally low modulus of rupture and corresponding high resistance to spalling in intermittent furnace service, which consists in mixing together dead burned magnesite as a major constituent and at least 35% of chrome ore in the form of from 55% to 70% of relatively coarse particles passing through a 5 mesh and resting upon a 35 mesh per linear inch screen, and relatively fine particles passing through a 50 mesh per linear inch screen, while substantially omitting particles of intermediate size, and having between 20% and 40% of relatively coarse dead burned magnesite in the mixture, inserting from 1% to 10% of kaolin and tempering the mixture, and inserting a bonding agent, forming the mixture into a brick at a pressure exceeding 5000 pounds per square inch and drying the brick to develop the bond as the final operation without firing prior to furnace use.

14. The process of forming and treating brick to provide basic roof brick and protect them from spalling, which consists in forming a green basic refractory brick by mixing dead burned magnesite as a major constituent and at least 35% of chrome ore as relatively coarse particles between 5 and 35 mesh per linear inch to an extent of between 55 and 70% of which the majority are magnesite, and fine particles through 55 mesh per linear inch of which the majority are also of magnesite, while substantially omitting the intermediate size of particles, employing 20 to 40% of coarse particles of dead burned magnesite, thereby producing a dry unfired brick of relatively higher modulus of rupture as compared with the fired brick so that advantage of this higher modulus of rupture can be taken at this point in transportation, suspending the brick from above and firing the exposed lower parts of the brick in use, whereby the upper parts of the brick remain unfired and retain their relatively high modulus of rupture and the lower parts of the brick which are exposed, including the adjacent parts within firing temperature in the heat gradient from the exposed face of the brick, are fired and their moduli of rupture are reduced and their resistances to compressive strain are reduced.

15. A basic refractory brick having provision for supporting it from above, containing dead burned magnesite as a major constituent and at least 35% of chrome, comprising from 55 to 70% of relatively coarse particles between 5 and 35 mesh per linear inch and relatively fine particles below 50 mesh per linear inch and substantially free from particles of intermediate sizes, in which from 20% to 40% of the mixture is composed of relatively coarse magnesite particles, the modulus of rupture after burning at 1500° C., as tested by A. S. T. M. Standard tests, is not more than 500 pounds per square inch and a maximum deflection of 0.0005'' when tested for modulus of rupture, and the volume shrinkage is less than 0.5% after five hours burning at 1650° C.

16. A basic refractory brick mix comprising relatively coarse particles between 5 and 35 mesh and relatively fine particles through 50 mesh per linear inch, and comprising relatively coarse chrome particles 30%, relatively coarse magnesite particles 35%, relative fine magnesite particles 20%, relatively fine chrome particles 10%, and relatively fine bauxite particles 5%.

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